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Chapter 5

Fostering Fertilizer Use and Welfare Distribution in Tanzania: Implications for Policy and Practice

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Additional information is available at the end of the chapter

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Abstract

This chapter attempts to assess the way the welfare effect is distributed among various players of the fertilizer supply chain and how fertilizer use can be promoted using micro fertilization technology. As policy debates over fertilizer use promotion have not yet come full circle, this chapter derives important implications for policy and practice. In particular, illustrations and economic-surplus effects framework were used to indicate expected impacts of fertilizer microdosing on crop yields and welfare. Low-dimension diagrammatic analysis using supply and demand curves was used together with detailed assessment of actors' interactions in the fertilizer supply chain. In terms of welfare, crop producers, consumers and other market agents gain more if fertilizer microdosing is adopted by farmers. However, the magnitude of welfare effects varies as the slope of demand and supply curves change due to marginal fertilizer costs, crop prices and yield responses. Other influencing factors are soil moisture, the microdose rate, cropping system and general farm management practices. Thus, fertilizer microdosing can easily foster fertilizer use if the country elites implement a rational consistent policy, hence improving the welfare of players if adoption of the technology is reinforced with an efficient fertilizer supply chain.

Keywords: welfare distribution, economic-surplus model, fertilizer microdosing, supply chain, Tanzania

1. Introduction

A plethora of scientific literature indicates that hunger is caused by poor soil fertility. In Sub-Saharan Africa, the gap between cereal consumption and production is the largest compared to other continents. The productivity of most food crops is not as good as expected [1, 2]. Thus, it is possible to secure food in African countries if soil fertility is improved as well as if there is

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an understanding of what works for smallholder farmers in rural areas [3]. Although small-scale farmers are a potential source of economic growth [4], more efforts are needed to rescue them from operating under low inputs and rain-fed agricultural conditions, which result in low yields and profits [5, 6]. It is worth noting that fertilizers account for the largest proportion of production costs component when compared with other farm inputs. Nevertheless, farmers in Tanzania have low levels of fertilizer use, hence low productivity [7, 8]. In this light, fertilizer use should be encouraged in order to improve productivity among farmers.

Investing on fertilizer use by smallholder farmers, including the application of recommended rates has been risky due to the scarcity of fertilizers and the unpredictability of rainfall [9, 10]. Fertilizer microdosing is likely to be a unique initiative that can encourage fertilizer use among the farmers community. The fertilizer microdosing technique is based on localized placement of small doses of mineral fertilizers ranging from 25–75% of the common rates at the base of the plants at sowing or shortly after seed germination instead of spreading fertilizers evenly across the field [9, 11]. This chapter focuses on how fertilizer use can be fostered to improve welfare among potential stakeholders of the fertilizer supply chain. Tanzania has been used as the fertilizer microdosing technology is rather new within the country and more understanding is needed associated with its impacts on fertilizer supply chain [12, 13]. In view of this, key implications are derived for policy and practice with the emphasis on fertilizer microdosing as an innovative low input technology that can replenish soil nutrients.

Some studies, although limited, seem to confirm that yields do relatively increase when fertilizer microdosing is applied [9, 14, 15]. However, in such studies, the issue of welfare distribution effects was rarely included to consider the benefits of fertilizer microdosing to producers and consumers [2, 11, 16]. In this regard, a separate welfare effects analysis urgently needs to be undertaken, targeting this farm-level technology [17], as it can easily be adopted by smallholder farmers in rural areas [18]. The available literature seems to be inapplicable as it mainly presents the impact of fertilizer microdosing in terms of yield responses. Actual impacts, indicating interactions between demand and supply and the role of price mechanisms have been marginally featured in the available literature. Likewise, the coverage on interactions of fertilizer supply chain actors at the national level seems to be scanty. Some of the key questions that remain unanswered include the following: what could be the impact of adopting fertilizer microdosing on the supply side and produced food prices? What are the likely changes in demand/supply of food crop produce, and to what extent is the resulting impact likely to differ from the cost of fertilizer used or return on investment?

While reviewing past economic studies related to fertilizer use, the researcher found inadequate information on welfare effects distributions of farm input use [15, 19]. In view of this, in the present chapter, the researcher build on the earlier studies to assess the welfare effects of fertilizer microdosing based on yield and prices. Based on this objective of the chapter, the contributions are twofold: first, little attention was noted on issues associated with crop responses and welfare in the on-going policy debates over modern input promotion [3, 20]. Thus, the researcher sought to learn from the economic theory and provide insights into the welfare effects that are likely to occur if fertilizer microdosing is adopted. In the same vein, the researcher sought to ascertain whether key actors, particularly farmers, are better off than before, and what factors are important for determining the outcomes, hence promote the

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technology. Second, in addition to contributing to the growing knowledge base on the welfare effects as prices of commodities change, the researcher extended the role of price analysis on welfare, beyond the output by considering the input (fertilizer) prices [21] and inter-temporal effects [22]. This study focuses on the way market functioning can affect the incentives of fertilizer supply chain actors using the available information gathered from previous studies. An investigation of how the input market should be improved is pertinent in understanding the underlying causes of low modern input use among producers and recommending best practice and policy for implementation [19, 23, 24].

2. Methods

The agricultural sector is controlled by market fundamentals such as forces of supply and demand. However, in reality, this is not always the case, as the market alone is not enough to allow equitable, sustained and stable growth [13]. In this regard, the demonstration of the partial equilibrium model using forces of supply and demand was used in this chapter, and a relevant literature review was undertaken to determine whether the supply chain performance and fertilizer markets functioning can improve through policy associated actions and government interventions. However, the main disadvantage of the economic-surplus approaches as reported is that the reliability of the findings usually depends on the extent to which the underlying parameters represent local conditions [25]. Keeping this constraint in mind, economic-surplus effects were determined and augmented with a thorough assessment of the fertilizer supply chain using Tanzania as a case. Integration of related approaches may be useful in support decisions, for instance, about better allocation of resources for promoting fertilizer use and investments [2].

2.1. Economic-surplus model for welfare analysis

As suggested by [26], this chapter uses fertilizer microdosing as an opportunity available for upgrading the agri-food value chains in Tanzania, targeting potential food crops [27]. It is the upgrading option that is within the reach of the weakest actor, i.e., the smallholder farmers [28]. An illustration and framework development of economic surplus (welfare and distribution) effects of the farm-level technology is of great importance for understanding the likely spillover of the new innovation [29]. Low-dimension diagrammatic analysis of expected impacts was used, based on the basic economic theory of supply and demand. In addition, a downward sloping demand curve and an upward sloping supply curve were used to characterize the domestic market for food crop produce. Thus, the choice of this methodological line comes from the fact that the economic-surplus approach requires the least information, is relatively easier to use and gives reliable results. According to [30], this method provides a relatively simple and flexible approach to understanding the value of adopting new technology by allowing for the comparison of the situations of with and without the use of the new technology. Details of the welfare impact results are portrayed in **Figure 1** and are further explained in the subsequent sections.

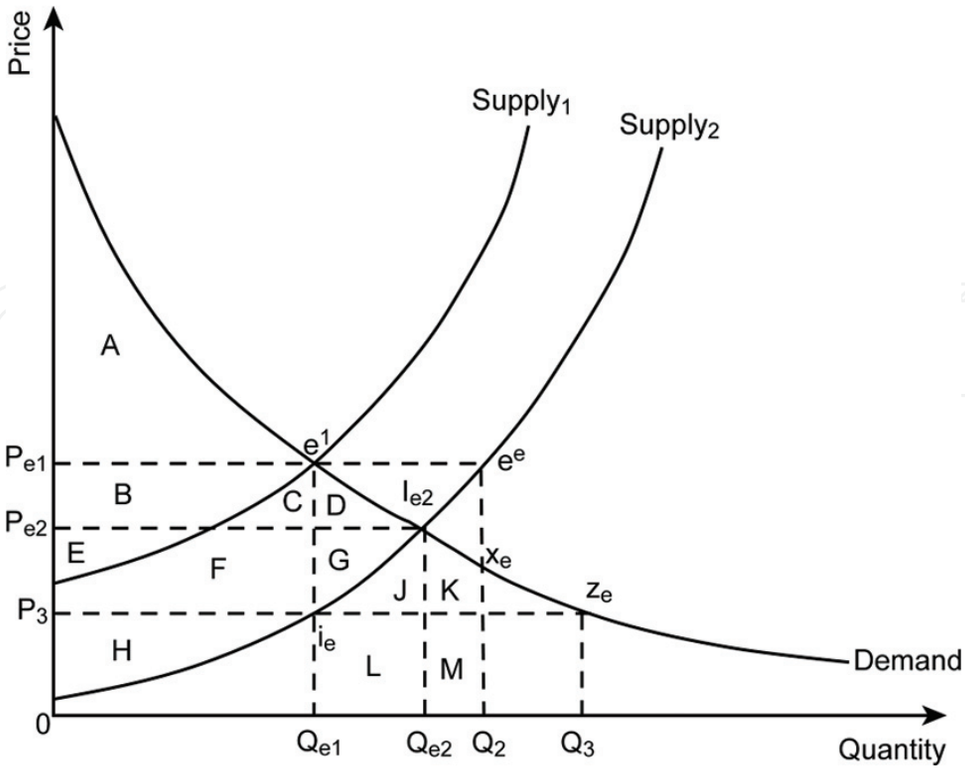


Figure 1. Impacts of fertilizer microdosing in supply.

2.2. The law of one price and its application

The law of one price is an economic theory that states that there is only one prevailing price for each product in a perfectly competitive market. Theoretically, price arbitrage works to dissipate price wedges between domestic and world or external market so that there is a stable tendency of domestic prices of a commodity to align with external prices [21]. In the context of this chapter, it is assumed that the movement of fertilizers from one market to the other will continue until the supply and demand forces equate the prices in both markets. It is further assumed that domestic fertilizer prices are embedded in the impact of domestic market and trade policies and actual functioning of farm-inputs markets. Therefore, the researcher has considered the law of one price as a relevant theory in underpinning the theoretical foundation of the chapter. In this regard, it has been noted that fertilizer microdosing, as an intermediary traded input, can transform the production process, given the availability of the primary factors of production, such as land, labor and capital. The value that is added through the production process, over and above the value (cost) of traded inputs (fertilizer), is value added [13]. Economic returns to the primary factors of production after the fertilizer microdosing has been applied by smallholder farmers are part and parcel of the welfare analysis presented. Moreover, additional reviews were undertaken to understand policy issues and conditions that prevent the law of one price from perfecting fertilizer supply chain as well as distribution, using Tanzania as a case.

3. Results

3.1. Response of fertilizer microdosing in supply

Here, the researcher analyses the economic impacts of fertilizer microdosing on a partial equilibrium model. **Figure 1** shows the market forces for a crop produce, with a standard upward sloping supply curve and downward sloping demand curve. Initially, the equilibrium is attained at point e^1 due to the price mechanism that ensures that demand and supply is equal. At this point, the price is Pe^1, and the quantity traded is Qe^1. The interpretation of this depicted situation can involve other intermediate activities of the supply chain, including transportation and storage. However, in the context of the chapter, they are hidden. For instance, better market functioning that result in favorable fertilizer prices to farmers is likely to encourage fertilizer use among producers; hence improve crop production [13].

Let us assume the scenario that smallholder farmers adopt fertilizer microdosing, which is a new farm-level technology in Tanzania. The supply curve (socially optimal supply curve) of the crop that would use fertilizer microdosing lies below the original supply curve, as shown in **Figure 1** by Supply^2. Given the original price Pe^1, more can actually be produced and supplied to the market (Q^2), or the original quantity Qe^1 can actually be produced at a much lower cost (P^3) if fertilizer microdosing is adopted. It should be noted that the new supply curve (Supply^2) due to fertilizer microdosing technology does not necessarily have to be parallel to the original supply curve (Supply^1). Comparatively, the extent of response due to fertilizer microdosing may vary with the scale of production, microdose rate and price [16]. Variation of yield responses due to fertilizer use also depends on the amount of moisture in the soil [31]. Access to adequate amount of soil moisture in semi-arid areas is a necessary condition for having a positive effect of fertilizer application [32]. Thus, the assumed scenario was used as a guide for providing required insights of the fertilizer microdosing and elucidating on its associated impacts.

3.2. Fertilizer microdosing impact on price, yields and welfare

As highlighted above, soil infertility poses the greatest threat in Tanzanian agriculture, and most of the farmers do not use fertilizers on their farms. What occurs in terms of supply if innovative low input technology such as fertilizer microdosing that replenishes soil nutrients is accepted by farmers for their cash and food crop production? Agro-dealers and other fertilizer suppliers/producers may, for example, be motivated to supply this farm input. This is particularly important considering that it is a new technology that makes business possible and worth undertaking and the emergence of new policies (regulations, taxes and subsidies) that penalize and/or incentivize players of the fertilizer supply chain. It is worth noting that increasing crop production due to fertilizer use surges, given the original demand curve and the underlying motivation of doing so. Such a situation results in a lower price, P_{e2}, and a higher equilibrium quantity, Q_{e2}, in the market, as given by point *e2*. At this new equilibrium point, consumers can buy more crop commodities/food at a lower price, resulting in a welfare gain to consumers as

measured in the area (B + C + D). Similarly, producers can sell more, but at a lower price, resulting in the PS of the area (E + F + G + H) minus area (B + E), which is also positive (**Figure 1**). The overall welfare gain due to fertilizer microdosing equals the sum of the change in the producer and the consumer surplus, which amounts to the area (C + D + F + G + H), the area between the new and old supply curves and under the demand curve, whereby, CS increased by C + D and a significant share of the welfare is favoring crop producers, presented by the area (F + G + H).

Note: $Supply_1$ and $Supply_2$ are the supply curves without and with fertilizer microdosing technology intervention respectively. $Supply_1$ represents the without fertilizer microdosing scenario, whereby, consumer surplus (CS) = area A, producer surplus (PS) = area (B + E), and total surplus (TS) = area (A + B + E). $Supply_2$ represents the with fertilizer microdosing scenario, whereby CS = area (A + B + C + D), PS = area (E + F + G + H), and TS = area (A + B + C + D + E + F + G + H). Therefore, welfare effects due to fertilizer microdosing in supply are represented by the area (C + D + F + G + H).

Welfare gains for both producers and consumers and other associated impacts such as a lower equilibrium price and higher quantity of food produced and consumed seem to be in line with other quantitative and qualitative studies undertaken on the impacts of farm-level technologies [11, 16]. The associated impacts of fertilizer microdosing can encourage fertilizer use in the perspective of low-income countries such as Tanzania, where insufficient crop productivity is a fundamental constraint. Based on **Figure 1**, it can also be noted that the magnitude of the impacts will depend, among others, on how crop yield (supply) effects are relative to the size of the market, which as reported earlier, varies by type of crop and farming system. Whatever the extent of the impact is, in terms of the quantity of crop produced due to fertilizer microdosing application, the size of the impact, $Q_{e1}Q_{e2}$, however, is smaller than the original size of the farm-level technology potentials, $Q_{e1}Q_2$, which is due to the change in the price. Farm technologies are output-increasing in nature. The observed impacts are supported by the recent literature and ex-ante approaches of various technologies along the agri-food value chain [33].

3.3. Inter-temporal welfare effects

The size of the welfare effects depends on the slope of the demand and supply curves. Let the assumption be that the extent of yield responses due to fertilizer microdosing application is the same as before, that is, the shift in the supply or demand curve is of the same distance as before, and independent of scale and/or price. The scenario considered and discussed in the context of this chapter focused on impacts on the outcomes of crop yields increase in supply. For instance, in the presence of a perfectly inelastic, that is, vertical demand curve, the new equilibrium is at point i_e (same quantity, lower price), with consumers receiving all the gains from increased yields in the form of a lower price and a welfare gain of $P_{e1}e^1i_eP_3$, which is equivalent to the area (B + C + E + F). In the presence of a perfectly elastic, that is, horizontal demand curve, additional crop yields in supply result in a new equilibrium at point e^e, where all the gains translate into an increase in the equilibrium quantity supplied and demanded. This implies that there is no change in price. As a result, this leads to welfare gain to producers of the area (C + D + F + G + H + I).

Distribution of welfare gains over producers and consumers can be influenced by varying the slope of the demand curve. Moreover, the sign does not change due to this slope change. As the demand for food is generally fairly inelastic (not perfectly), the actual scenario is likely to lie in between the two extreme cases shown. Less than one in absolute value (inelastic) estimates of elasticity of demand for food most of the time vary by type of food, and many also vary by income level [34]. Because basic food commodities such as staple foods were considered by our case, the demand will be more inelastic. Likewise, if supply is perfectly inelastic (i.e., a vertical supply curve), the equilibrium is at point x_e, resulting in a lower equilibrium price and higher equilibrium quantity compared to what was analyzed before. This implies that consumers gain and producers lose. However, the overall welfare result is positive under $e^1x_eQ_2Q_{e1}$, which is the area (D + G + J + K + L + M). Finally, a completely elastic (i.e., horizontal supply curve) results in equilibrium at point z_e, whereby demand increases the most to Q_3 as the price also falls the most to P_3, and all welfare gains end up with the consumers who benefit to the maximum extent possible, by the area under $P_{e1}e^1z_eP_3$.

A vertical supply curve is representative of the short-run, where it is generally difficult for farmers to respond to price changes, whereas the horizontal supply curve corresponds to a long-run situation, where producers of agri-food commodities can respond. However, farmers in this situation are price takers in a highly competitive market. The actual representation is likely to lie somewhere in between, with the short-run and long-run situations being closer to inelastic and more elastic, respectively. These findings imply the importance of inter-temporal effects, which seem to have been ignored in the available literature [29]. To be more specific, the overall welfare and the welfare of consumers in particular improve while that of producers declines, implying that the supply is relatively inelastic. Thus, in the short-run situation, the increase in sales from extra yields due to fertilizer microdosing could be insufficient to compensate for the price decrease on existing sales. In the long-run situation, the supply of crop produce is more elastic. In view of this, welfare gains are likely to occur, and most of the gains end up with consumers.

3.4. Fertilizer microdosing interactions and performance of the fertilizer supply chain

Some assumptions were made to arrive at the presented results. Variations of the findings could result from the influence of other factors. At this point, discussions of various impressions on the viability of fertilizer microdosing technology have been presented. The focus has been on how the impacts of fertilizer microdosing technology can be sustained by considering other interactions of fertilizer supply chain. The researcher has also identified some factors that may alter the anticipated impact of fertilizer microdosing, hence improved welfare.

3.4.1. Impact of fertilizer microdosing on economic returns

Development of low-input soil fertility management practice for crops is vital [35] in a wider range of cropping systems in semi-arid and sub-humid areas [12]. Fertilizer microdosing can be a better option that can be relied upon by smallholder farmers in rural areas [9]. However, before the adoption of technology is cascaded, there was a need to undertake a comprehensive economic analysis, by taking into account the associated risks [19, 36]. It was reported in sub-

humid farming system that fertilizer microdosing (25, 50 and 75% of recommended rates) can be applied to maize farms and result in positive net return distributions [16]. Because soil moisture is a problem in semi-arid areas, fertilizer microdosing was found to be more effective if and when combined with rainwater harvesting technology. A potential economic gain was further noted from sunflower compared to other crops such as pearl millet and groundnuts. Direct impacts of fertilizer microdosing technology on yields and profit changes with the level of moisture in the soil, micro-dose rate, cropping system and general farm management practices.

3.4.2. Enhancing fertilizer microdosing impacts

There are costs associated with access and the application of a farm-input, and for this case, fertilizers. While the underlying causes for low fertilizer use are still debatable [37], the main notion behind fertilizer microdosing technology is to encourage farmers to use fertilizer after experiencing the associated benefits, including higher yields [9]. This farm technology is more feasible if costs associated with its use would be reduced to the level affordable by farmers [16], considering that fertilizer can account for up to 35% of the total crop production costs [8]. The government and other partners can play an important role in improving the distribution of farm inputs, rendering extension services on how best fertilizers can be applied to different cropping systems and stimulating adoption of the technology. Comparatively, the net welfare gains may be lower if there are excess costs related to fertilizer use, incurred by producers, which counteract the original shift of the supply curve [20]. However, farmers can organize themselves into strong groups and use them as platforms for collective farm-inputs procurement.

3.4.3. Interactions within the fertilizer supply chain

The economic-surplus framework presented earlier cannot suffice to describe concerns emanating from the fertilizer supply chain. Measures to address issues in the fertilizer supply chain may vary significantly. For example, there could be no problem in the beginning of the supply chain, but costs and benefits may occur later in the chain and affect potential players. Fertilizer subsidy can stimulate the supply side and encourage fertilizer application to the lowest fertilizer users in the world, including Tanzania [8, 38]. However, fertilizer subsidy schemes that are convenient, transferable, and sustainable are needed for farmers who are not using fertilizers at all [39]. It should be noted that following the subsidy removal and devaluation in Tanzania, sharp declines in fertilizer use were observed [37], implying that any structural adjustment should not be detrimental to fertilizer markets in the country. Thus, improvement in inputs market functioning with a strategic investment in public goods is a potential way forward for countries such as Tanzania [24].

It should be noted that structural adjustment is the only factor that affects fertilizer prices among other factors, and fertilizer prices, however, are one of the several factors that influence fertilizer use [40]. As far as welfare distribution is concerned, fertilizer subsidies cannot only lower food prices in favor of consumers but also increase rural wages to key players of the supply chain. In general, market infrastructure, similar to other factors such as soil moisture conditions, cropping systems and extension systems, has a great role to play, and it must be considered as far as fertilizer use is concerned [20]. For example, when the fertilizer-crop price ratio is not favorable

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to farmers due to market failures, government intervention is inevitable for incentives and welfare enhancing [8, 13, 21]. Fertilizer distribution systems need to be improved for farmers in marginal areas, as they are less likely to use fertilizer and adopt new technology than those in higher potential areas. This is also an indication that agricultural input markets, particularly those for fertilizers and seeds, require more rigorous policy actions that are location based and context-specific [20].

3.4.4. Interactions with other commodity markets and players

A contrasting assumption that all factors remain constant was considered in the analysis. For instance, higher crop yields due to fertilizer microdosing application result in lower prices of the crop commodity in the market, which could also increase demand elsewhere in the system and hypothetically lead to second-order impacts. To be more explicit, higher cereal yields from crops, such as maize, which are used as chicken feed, become cheaper if fertilizer is used in the farm. Nevertheless, if the supply of the chicken feed declines due to changes in price, the local chicken meat demand is likely to rise, and prices for the same will essentially rise. The idea is that local chicken are less efficient in the use of resources such as water and land compared to crops [41]. Moreover, the effects of fertilizer can be boosted by manures because when they are used together, they tend to be more effective on crop yields [42]. However, the use of manures in rural areas is limited by the availability of sufficient quantities. From this observation, it would seem that crop-livestock integration could be further enhanced for more food and income diversification.

Although soil water is a necessary condition for realizing a significant impact of fertilizer use, improved seeds are similarly a key constituent. It should be noted that soil moisture is not a serious problem in sub-humid farming system as in semi-arid areas. In this light, fertilizer microdosing can be applied effectively in sub-humid areas and have the desired impact realized [16, 32]. Thus, there is need of introducing rainwater harvesting or irrigation technologies in semi-arid areas for fertilizer use technology to be employed and cope with climatic

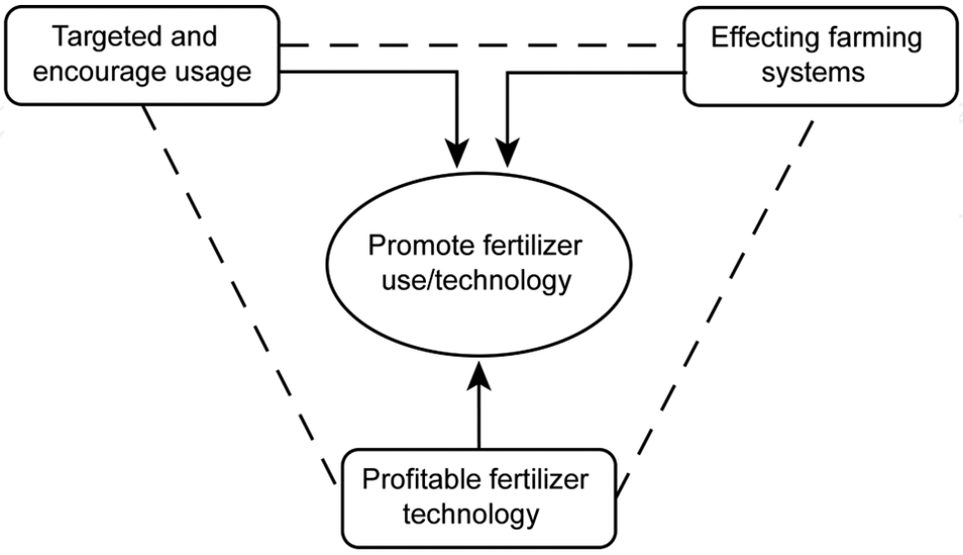


Figure 2. Promoting fertilizer use and microdosing technology in Tanzania.

variability conditions [31, 43]. In Tanzania, there is an effective locally manufactured fertilizer known as Minjingu Mazao. This fertilizer use technology can be featured in the government input subsidy programs, as experience has shown that the imported fertilizers meant for subsidizing crop production do not reach farmers. It has been reported that the imported fertilizers are being sold to unintended people, hence affecting the intended farmers [20]. Farmers are unlikely to benefit from the current yield gains as their depleted soils are non-responsive to fertilizer application [44]. In view of this, an understanding of the possible marginal yield/income responses across different agro-ecological zones of a country is needed before investing much in soil nutrient inputs such as fertilizer microdosing. In addition, more can be done to promote fertilizer use related technologies in Tanzania and beyond (**Figure 2**).

4. Discussion

4.1. A synthesis

An economic theory shows that the impacts of crop yields due to fertilizer microdosing, application as a farm-level technology in supply and in terms of quantity are different from the original size of the yields. In other words, the extent of the yields obtained is influenced by the amount and the way fertilizer was applied, costs associated with fertilizers, level of food prices, size of the fertilizer market and interactions within the fertilizer supply chain and with other players and markets. It is also evident that impacts change with the slope of the demand and supply curve and consumer preference or level of the technology adoption, which play an important role in the demand size of fertilizers. If all of these influencing factors are considered, one cannot be sure of the likely impact of the fertilizer application in the context of welfare and food security.

Table 1 presents the results of the supply and demand side analyses of applying fertilizer microdosing on infertile soil that has an appropriate amount of soil moisture. It summarizes

Increasing yields in supply	**Impact on market equilibrium**		**Welfare impacts in the commodity market**			**Factor of influence and impacts**
	Price	Quantity	Consumers	Producers	Total	Extent of yields increase relative to the size of the fertilizer market
Perfectly elastic supply curve	–ve	+ve	+ve	Constant	+ve	Interactions within the fertilizer supply chain and with other players
Perfectly inelastic supply curve	–ve	+ve	+ve	–ve in example	+ve	If fertilizer use involves costs, then welfare impacts will be lower.
Perfectly elastic demand curve	Constant	+ve	Constant	+ve	+ve	Impacts may be smaller if costs associated with technology are high.
Perfectly inelastic demand curve	–ve	Constant	+ve	Constant	+ve	If fertilizer use decreases, the impacts are larger at a lower scale and price.

Table 1. Overview of the impacts of increasing yields in the market as fertilizer microdosing is applied in a food commodity.

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what happens to the market equilibrium. Whereas the second and third columns show the price and quantity of food commodity, respectively, consumer and producer welfare are shown in the fourth and fifth columns, respectively. The overall effect of the welfare is presented in the sixth column. This scenario was assumed to occur in the market for the food commodity in question and for varying assumptions regarding demand and supply curves, providing the boundaries by rows for what might occur. The last column indicates the impact of other factors that are of influence, where possible, relaxing some of the simplifying assumptions made throughout the analyses. The following subsections present the implications for policy and in practice, and briefly highlight the aforementioned studies on the farm-level economic impacts of fertilizer microdosing in Tanzania.

4.2. Promoting fertilizer microdosing technology

Promoting the farm-level technology that can encourage farmers to use fertilizers in a country is a key for improving crop productivity [12]. However, there are some factors that need consideration before adopting and promoting technology such as fertilizer microdosing. First, the starting point for encouraging fertilizer use among farmers should be identified. Farmers in a country such as Tanzania are of different scales, and for this reason, fertilizer microdosing can target small-scale farmers who cultivate farms of less than a hectare. The technology is useful to farmers who do not use fertilizers, as they are motivated to use more after finding it is profitable. Because smallholder farmers are resource poor, the government can reduce the cost of the technology by appropriately subsidizing the fertilizers and improve access of fertilizers at the village level [16, 45].

Fertilizer microdosing can be more cost-effective if the government addresses potential market failures within the fertilizer supplier chain. [46] Suggested focusing on a holistic approach by addressing five pillars of market development and supporting conditions for effective functioning fertilizer markets. The pillars include policy, human capital, finance, market information and regulation. Crop yields can be improved with the efficient use of the technology, which goes hand in hand with the provision of opportunities for acquiring necessary knowledge and skills to targeted farmers and linking them with input suppliers [20].

In addition, after the adoption of the fertilizer microdosing technology by farmers with or without subsidization, the technology should have positive impacts on country farming systems. Testing the effectiveness of technology for upgrading agri-food value chains in sub-humid and semi-arid farming systems was important in Tanzania [12, 27]. For instance, marginal yields due to fertilizer microdosing should be high enough to motivate farmers to use fertilizers and adopt the technology. Moreover, better yields in semi-arid areas can be obtained if the fertilizer microdosing is combined with rainwater harvesting technology, particularly through tied-ridges.

The second factor is related to the third one, that is, the technology contributes significantly economic returns, hence being profitable to farmers. It is envisaged that farm-level technology should increase the output. However, additional crop yield due to fertilizer microdosing is a necessary but not sufficient condition for obtaining net returns. Empirical evidence shows that

fertilizer microdosing can have significant impacts on both yield and income in sub-humid rather than in semi-arid farming systems. Variability in soil quality, soil moisture, and fertilizer market costs influence considerably the response and distribution of crop yields and rewards [16]. This type of technology can be promoted at the country level, as it can improve agricultural growth and alleviate poverty [31, [47], **Figure 1**. **Figure 2** presents a summary of the described factors and the way they are related to the promotion of fertilizer use and technology, in this case, fertilizer microdosing.

4.3. Implication for policy

At this point, it is evident that the microdosing strategy can inspire farmers to use more fertilizers. As policy debates on fertilizer use promotion are on-going [20], issues related to crop responses due to fertilizer microdosing have been presented from the context of localized application. Key messages that can be considered for policy actions have been highlighted to guide policy makers in re-shaping the existing policies or formulate new ones with a view of improving soil fertility as a key input for increased crop yields and profitability. It has been noted that fertilizer microdosing is a cost-effective farm-level technology that requires more resource attention.

Moreover, fertilizer-output price rations were found to be unfavorable due to market failure, including inadequate provision of necessary market linked infrastructures [12, 24]. The government can intervene and enhance the welfare of all key players in the fertilizer supply chain and markets by balancing the outcome of the trade-offs, including reducing the tax level of locally manufactured fertilizers. For example, as shown in **Figure 2**, smart fertilizer subsidies that are effective and sustainable can be used to support the application of fertilizer microdosing technology for pro-poor growth in Tanzania. However, policy measures from the government side should be predictable to enable farmers to make proper choices for farm inputs.

4.4. Implication for practice

Fertilizer microdosing can provide solutions to farmers and other players of the fertilizer supply chain. The outcome of the applied research that works on innovative solutions can benefit a wide range of supply chain actors. For example, farmers are likely to have higher returns on investment if they adopt fertilizer microdosing in the production of important crops, such as maize [16]. It is expected that with the adoption of technology, the demand for associated farm-inputs will be triggered, hence profitable to input producers, trades and other market agents.

Based on this, future studies and policy makers will be provided with information on how to improve soil quality and the modern input supply chains. The information will also be useful in understanding constraints, such as soil infertility and ineffective supply chains and possible solutions for addressing these issues. Moreover, detailed information at the national level about the composition of soil micronutrients would determine appropriate ways of using fertilizers, hence ensuring high productivity and profitability.

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In this regard, policy, practice and future research tend to inform and benefit one another. If people's knowledge on the causal-impact of fertilizer microdosing is enhanced, it will enable the refinement of policies and result in better outcomes among the essential players in the fertilizer supply chain.

5. Concluding remarks

This review has revealed how economic theory can be used to provide intuitions of the welfare effects to various players of the supply chain if fertilizer microdosing technology is adopted. The overall welfare gains to crop producers, consumers and other market agents due to fertilizer microdosing application have been found to be positive. Moreover, the size of the welfare impacts changes as the slope of the demand and supply curves change, given the crop yield responses as a result of fertilizer use and micro fertilization application. This implies the importance of inter-temporal effects in the market where farmers are considered as price takers. Other factors that seem to influence crop yield and profit responses have been highlighted. These include soil moisture, the micro-dose rate, cropping system and general farm management practices. In addition, interventions that can be undertaken by the government and other players for improving the efficiency of the fertilizer supply chain have been highlighted.

This chapter has important policy and practice implications. The findings suggest that in a country such as Tanzania, where investment in physical infrastructures are limited, more is supposed to be done in terms of investing in functional seed and fertilizer markets, road networks, storage facilities and market information systems. Thus, a rational policy choice for a country should promote fertilizer use through embracing farm-level technologies such as fertilizer microdosing by considering the entire fertilizer supply chain. More resources can then be allocated in order to improve the welfare and living conditions of key players, particularly in rural areas. At this juncture, it could be concluded that fertilizer microdosing technology is worth adopting as it enhances agricultural growth and reduces poverty.

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References

[1] Matshe I. Boosting smallholder production for food security: Some approaches and evidence from studies in sub-Saharan African. Agrekon. 2009;**48**(4):483-511

[2] Mourice SK, Rweyemamu CL, Nyambilila AA, Tumbo SD. Narrowing maize yield gaps under rain-fed conditions in Tanzania: Effects of small nitrogen dose. Tanzania Journal of Agricultural Sciences. 2014;**12**(2):55-65

[3] Gilbert N. African agriculture: Dirt poor. Nature. 2012;**483**:525-527

[4] Cairns JE, Hellin J, Sonder K, Araus JL, MacRobert JF, Thierfelder C, Prasanna BM. Adapting maize production to climate change in sub-Saharan Africa. Food Security. 2013;**5**:345-360

[5] Kalhapure AH, Shete BT, Dhonde MB. Integrated nutrient management in maize (Zea mays L.) for increasing production with sustainability. International Journal of Agriculture and Food Science Technology. 2013;**4**(3):195-206

[6] Kristjanson P, Neufeldt H, Gassner A, Mango J, Kyazze FB, Desta S, et al. Are food insecure smallholder households making changes in their farming practices ? Evidence from East Africa. Food Security. 2012;**4**:381-397

[7] URT (United Republic of Tanzania). National Sample Census of Agriculture 2007/2008 Vol. 5e: Morogoro Regional Report. Dar es Salaam: National Bureau of Statistics; 2012

[8] Wilson RT, Lewis J. The Maize Value Chain in Tanzania. A Report from the Southern Highlands Food Systems Program. Rome: FAO; 2015

[9] Camara BS, Camara F, Berthe A, Oswald A. Micro-dosing of fertilizer – A technology for farmers' needs and resources. International Journal of AgriScience. 2013;**3**(5):387-399

[10] de Graaff J, Kessler A, Nibbering JW. Agriculture and food security in selected countries in sub-Saharan Africa: Diversity in trends and opportunities. Food Security. 2011;**3**:195-213

[11] Twomlow S, Rohrbach D, Dimes J, Rusike J, Mupangwa W, Ncube B, et al. Micro-dosing as a pathway to Africa's green revolution: Evidence from broad-scale on-farm trials. Nutrient Cycling in Agroecosystems. 2010;**88**:3-15

[12] Graef F, Sieber S, Mutabazi K, Asch F, Biesalski HK, Bitegeko J, et al. Framework for participatory food security research in rural food value chains. Global Food Security. 2014;**3**(1):8-15

[13] MAFAP. Review of food and agricultural policies in the United Republic of Tanzania 2005–2011, (July). MAFAP Country Report Series. Rome: FAO; 2013

[14] Hayashi K, Abdoulaye T, Gerard B, Bationo A. Evaluation of application timing in fertilizer micro-dosing technology on millet production in Niger, West Africa. Nutrient Cycling in Agroecosystems. 2008;**80**:257-265

[15] Tabo R, Bationo A, DialloMaimouna K, Kassane O, Koala S. Fertilizer Microdosing for the Prosperity of Small Scale Farmers in the Sahel: Final Report. Sadore, Niger: International Crop Research Institute for the Semiarid Tropics (ICRISAT); 2005

[16] Mwinuka L, Mutabazi KD, Makindara J, Sieber S. Reckoning the risks and rewards of fertilizer micro-dosing in a sub-humid farming system in Tanzania. African Journal of Science, Technology, Innovation and Development. 2016;**8**(5–6):497-508

[17] Farquharson RJ, Martin RJ, Mccorkell B, Scott JF, Sotheary E, Phaloeun C, et al. Characteristics of an agricultural innovation and incentives for adoption: Rhizobium in Cambodia. International Journal of Environmental and Rural Development. 2013;**4**(2):44-39

[18] Mwinuka L, Mutabazi KD, Graef F, Sieber S, Makindara J, Kimaro A, Uckert G. Simulated willingness of farmers to adopt fertilizer micro-dosing and rainwater harvesting technologies in semi-arid and sub-humid farming systems in Tanzania. Food Security. 2017;**9**(6): 1237-1253

[19] Asci S, Borisova T, VanSickle JJ. Role of economics in developing fertilizer best management practices. Agricultural Water Management. 2015;**152**:251-261

[20] Jayne TS, Mather D, Mason N, Ricker-Gilbert J. How do fertilizer subsidy programs affect total fertilizer use in sub-Saharan Africa? Crowding out, diversion, and benefit/cost assessments. Agricultural Economics. 2013;**44**:687-703

[21] Short C, Barreiro-Hurlé J, Balie J. Policy or markets? An analysis of price incentives and disincentives for rice and cotton in selected African countries. Canadian Journal of Agricultural Economics. 2014;**62**(4):441-469

[22] Rutten MM. What economic theory tells us about the impacts of reducing food losses and/or waste: Implications for research, policy and practice. Agriculture and Food Security. 2013;**2**:13

[23] Mghenyi E, Myers RJ, Jayne TS. The effects of a large discrete maize price increase on the distribution of household welfare and poverty in rural Kenya. Agricultural Economics. 2011;**42**:343-356

[24] von Braun J. Addressing the food crisis: Governance, market functioning, and investment in public goods. Food Security. 2009;**1**:9-15

[25] Falck-Zepeda J, Horna D, Smale M. Betting on cotton: Potential payoffs and economic risks of adopting transgenic cotton in West Africa. The African Journal of Agricultural and Resource Economics. 2008;**2**(2):188-207

[26] Gibbons P. Commodities, Donors and Value-Chain Analysis and Upgrading. DIIS Paper Prepared for UNCTAD; 2003

[27] Mwinuka L, Mutabazi KD, Graef F, Maeda C, Makoko B, Swai E. Agri-Food Value Chains Upgrading Strategies Choices: A Participatory Smallholder Farmer Centred Approach. Plant2030 Status Seminar. Berlin 4th–6th March 2015;2015a

[28] Sanogo I. How to Conduct a Food Commodity Value Chain Analysis? Technical Guidance Sheet (TGS) Prepared under ENCAP-Enhance Capacities in Food Security and Response Analysis. World Food Program; 2010

[29] Cook DC, Carrasco LR, Paini DR, Fraser RW. Estimating the social welfare effects of New Zealand apple imports. The Australian Journal of Agricultural and Resource Economics. 2011;**55**:599-620

[30] Mensah EC, Wohlgenant MK. A market impact analysis of soybean technology adoption. Research in Business and Economic Journal. 2010;**1**:142-159

[31] Reynolds TW, Waddington SR, Anderson CL, Chew A, True Z, Cullen A. Environmental impacts and constraints associated with the production of major food crops in sub-Saharan Africa and South Asia. Food Security. 2015;**7**:795-822

[32] Fufa B, Hassan RM. Determinants of fertilizer use on maize in eastern Ethiopia: A weighted endogenous sampling analysis of the extent and intensity of adoption. Agrekon. 2006;**45**(1):38-49

[33] Graef F, Uckert G, Schindler J, König HJ, Mbwana HA, Fasse A, et al. Expert-based ex-ante assessment of potential social, ecological, and economic impacts of upgrading strategies for improving food security in rural Tanzania using the ScalA-FS approach. Food Security. 2017. DOI: 10.1007/s12571-016-0639-x

[34] Andreyeva T, Long M, Brownell K. The impact of food prices on consumption: A systematic review of research on the price elasticity of demand for food. American Journal of Public Health. 2010;**100**:216-219

[35] Mwinuka L, Schneider I, Maeda C, Mutabazi KD, Makindara J, Graef F, et al. Comparing stakeholder views for mutual acceptable food value chain upgrading strategies in Tanzania. African Journal of Agricultural Research. 2015b;**10**(12):1376-1385

[36] Richardson JW, Herbst BK, Outlaw JL, Gill RC II. Including risk in economic feasibility analyses: The case of ethanol production in Texas. Journal of Agribusiness. 2007;**25**(2):115-132

[37] Rashid S, Jayne TS, Minot N. Modern Input Promotion in Africa: Overview of Evidence and Future Policy Direction. Prepared as the Background Paper for the Annual Trend and Outlook Report (ATOR) of the Regional Strategic Analysis and Knowledge Support Systems (ReSAKSS); 2015

[38] Benson T, Kirama SL, Selejio O. The Supply of Inorganic Fertilizer to Smallholder Farmers in Tanzania. IFPRI Policy Note 17. Washington, DC: International Food Policy Research Institute (IFPRI); 2013

[39] Druilhe Z, Barreiro-Hurlé J. Fertilizer Subsidies in Sub-Saharan Africa. ESA Working paper No. 12–04. Rome: FAO; 2012

[40] Minot N, Benson T. Fertilizer Subsidies in Africa: Are Vouchers the Answers? Washington, DC: International Food Policy Research Institute; 2009

[41] Hoekstra A. The hidden water resource use behind meat and dairy. Animal Frontiers. 2012;**2**:3-8

[42] Aune JB, Bationo A. Agricultural intensification in the Sahel–The ladder approach. Agricultural Systems. 2008;**98**(2):119-125

[43] Cooper PJM, Dimes J, Rao KPC, Shapiro B, Shiferaw B, Twomlow S. Coping better with current climatic variability in the rain-fed farming systems of sub-Saharan Africa: An essential first step in adapting to future climate change? Agriculture, Ecosystems and Environment. 2008;**126**:24-35

[44] Tittonell P, Vanlauwe B, de Ridder N, Giller K. Nutrient use efficiencies and crop responses to N, P, and manure applications in Zimbabwean soils: Exploring management strategies across soil fertility gradients. Field Crop Research. 2007;**100**:348-368

[45] Pan L, Christiaensen L. Who is vouching for the input voucher? De-centralized targeting and elite capture in Tanzania. World Development. 2012;**40**(8):1619-1633

[46] Gregory DI, Bumb BL. Factors Affecting Supply of Fertilizer in Sub-Saharan Africa. Agriculture and Rural Development Discussion Paper 24. Washignton, DC: The World Bank; 2006

[47] Pauw K, Thurlow J. Agricultural growth, poverty, and nutrition in Tanzania. Food Policy. 2011;**36**(6):795-804

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